Climate Predictability on Seasonal, Interannual and Decadal Scales

- Research Advances on Climate Estimation and Prediction Initialization

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Frontiers in Climate and Earth System Modeling: Advancing the Science

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Motivations of Data Assimilation for Climate Studies

Goal

Understanding climate variability to better estimate and predict climate on seasonal-interannual to decadal scales

Challenges

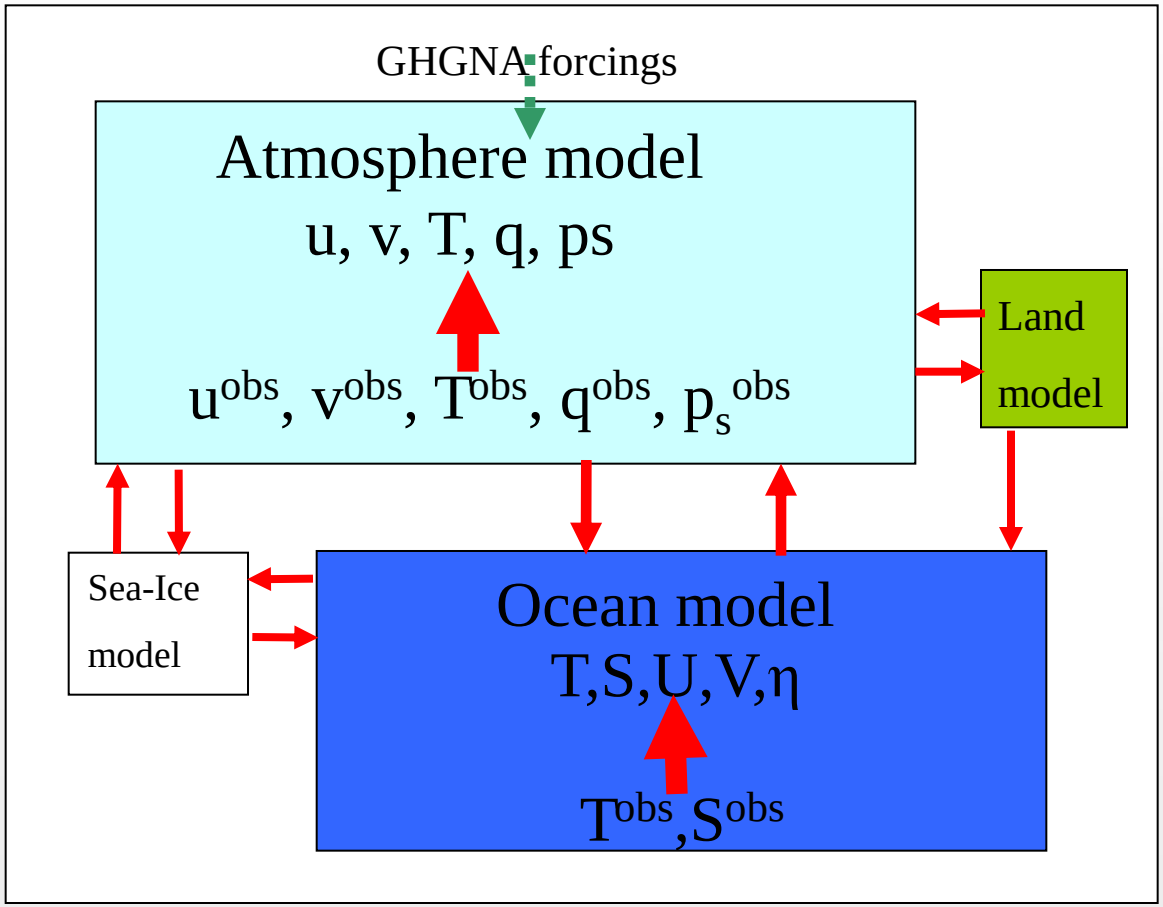
- Models produce different climate features and variability from the real world due to modeling errors and uncertainties.
- Observations have sampling and representation errors.

Methodology

Combining observed data with a climate model using Ensemble Coupled Data Assimilation

Coupled Data Assimilation (CDA)

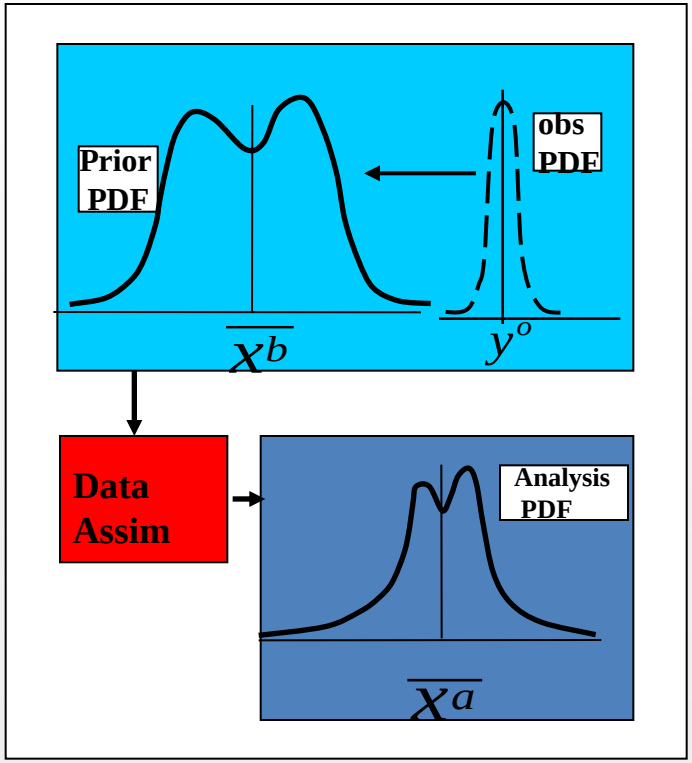
CDA is good for climate studies – All coupled components adjusted by observed data through instantaneously-exchanged fluxes



Ensemble Coupled Data Assimilation (ECDA)

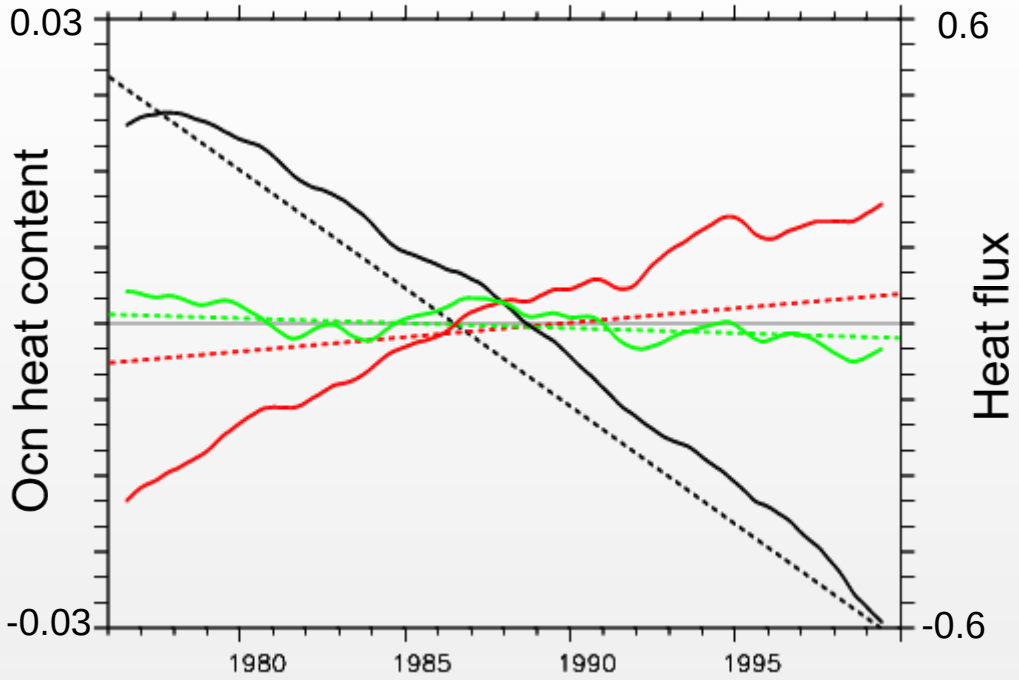
ECDA is optimal for climate studies – An ensemble of model integrations establishing the background error statistics to extract the observational information, addressing the probabilistic nature of climate evolution.

- ✓ Ensemble statistics provide multivariate relationships, such as temperature-salinity relationship and geostrophic balance
- ✓ A set of self-balanced and coherent initial coupled states generates optimal ensemble initialization of coupled model with minimum initial shocks



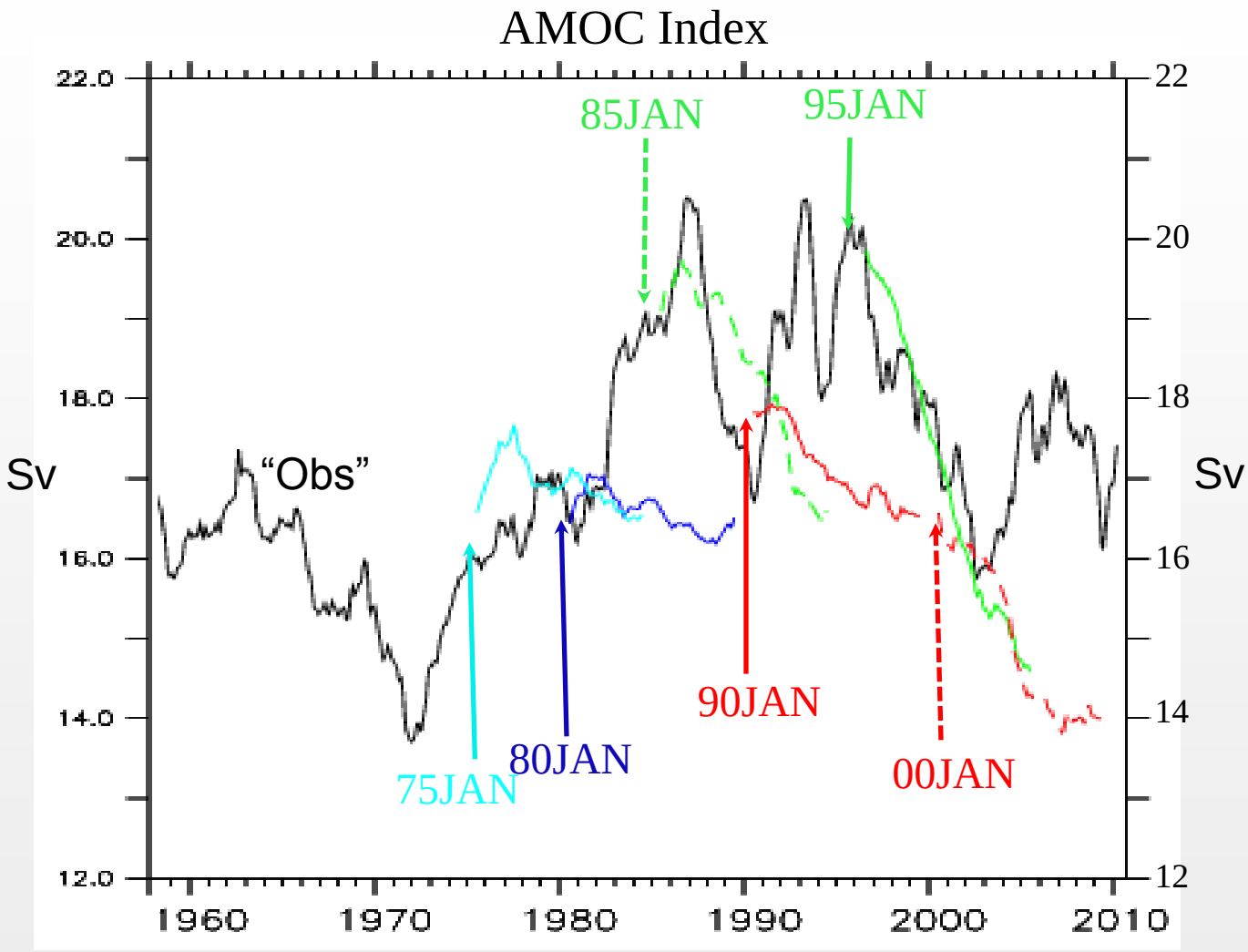
Combining data with an imperfect coupled model for energy-balanced climate estimation

Using one model results as truth and another model to assimilate the "truth" to illustrate the advantage of coupled data assimilation



(Thanks to XYang, YChang & ARosati)

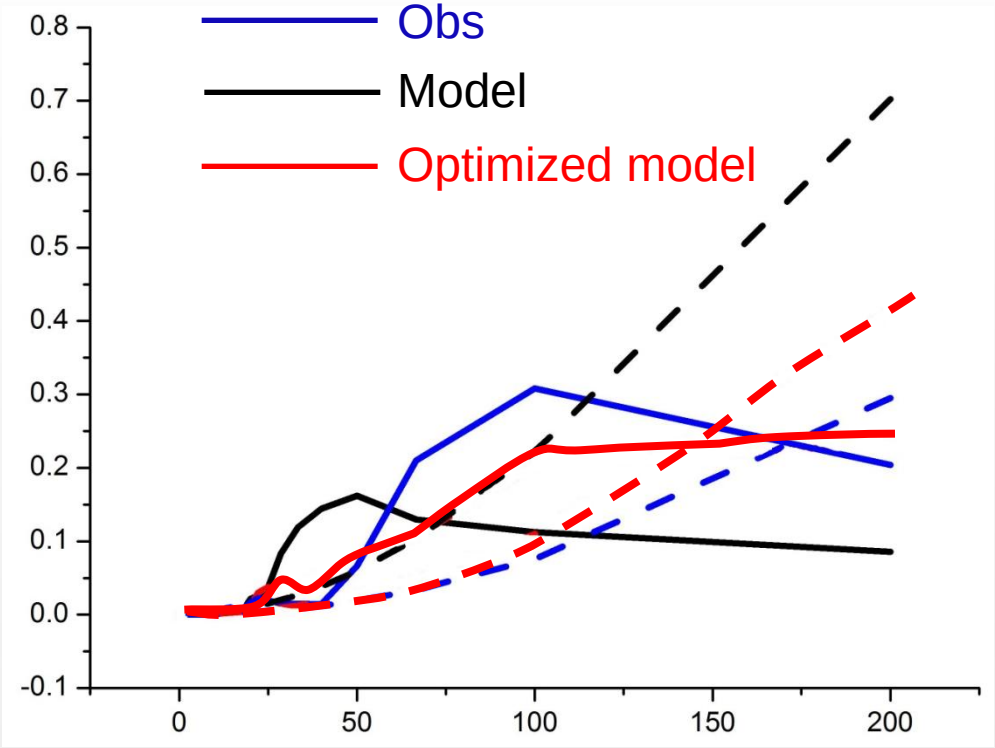
Challenge: model bias causing climate drift hinders prediction



Impact of parameter estimation on model simulation

- ✓ Two different long-wave radiation parameterization schemes in a coupled model simulate a biased climate problem caused by biased physics
- ✓ Scheme-I: Obs
- ✓ Scheme-II: **Model**
- ✓ Optimized model: parameters are optimized using Ensemble Coupled Data Assimilation

power spectrum of ocean temp variability



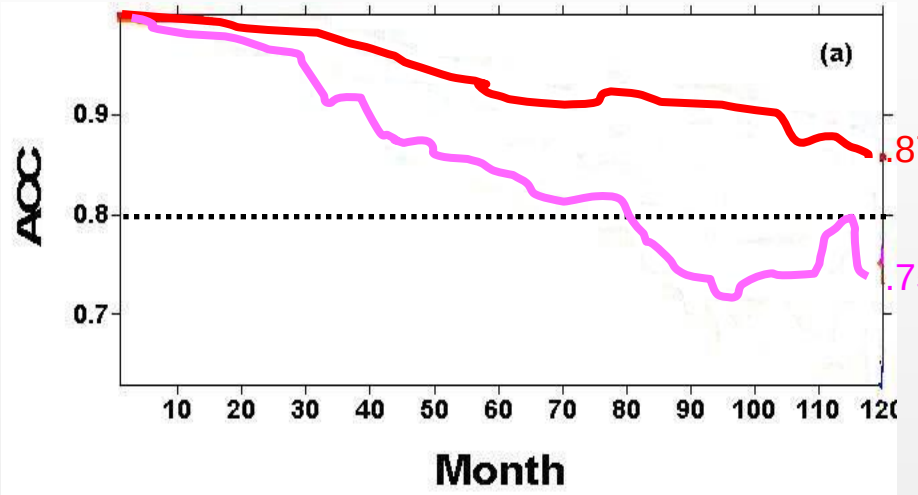
(Thanks to XZhang, GVecchi & IHeld)

Impact of parameter estimation on model predictability

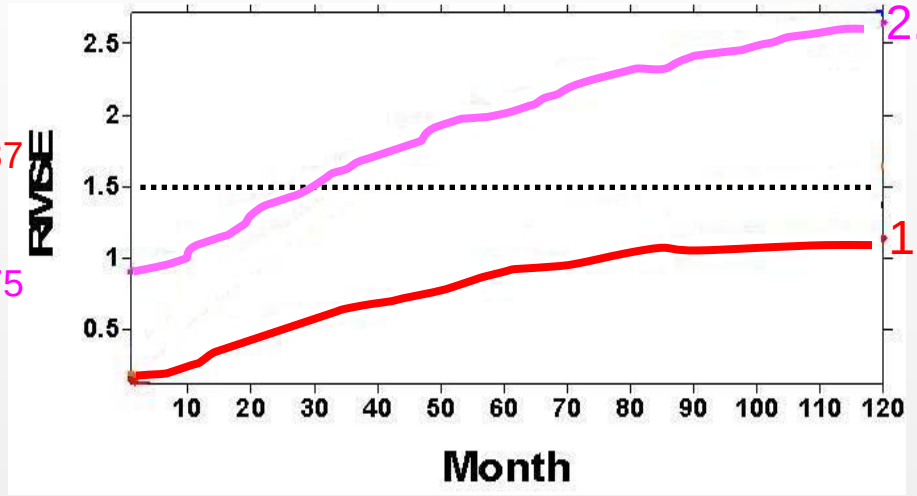
Ocean temperature forecast skill

Traditional State Estimation

New State Estimation+Parameter Estimation



Forecast lead time



Forecast lead time

Reconstruction of tropical storm statistics in high-resolution coupled data assimilation

A high-resolution coupled model at GFDL: CM2.5 (½º x ½ º Atm & ¼º x ¼ º Ocn)

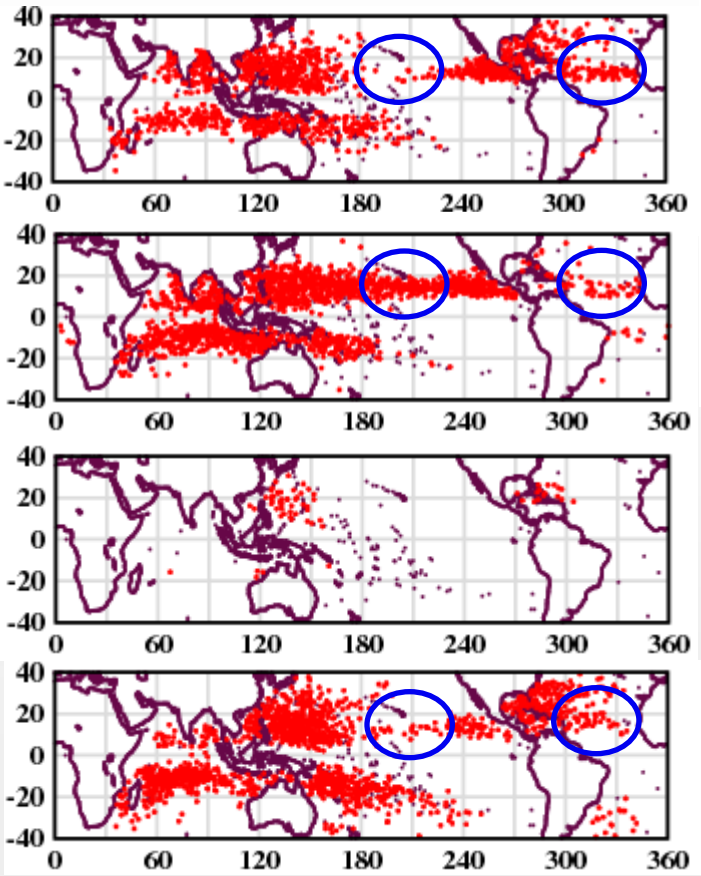
Total TCs (99-11)

Obs

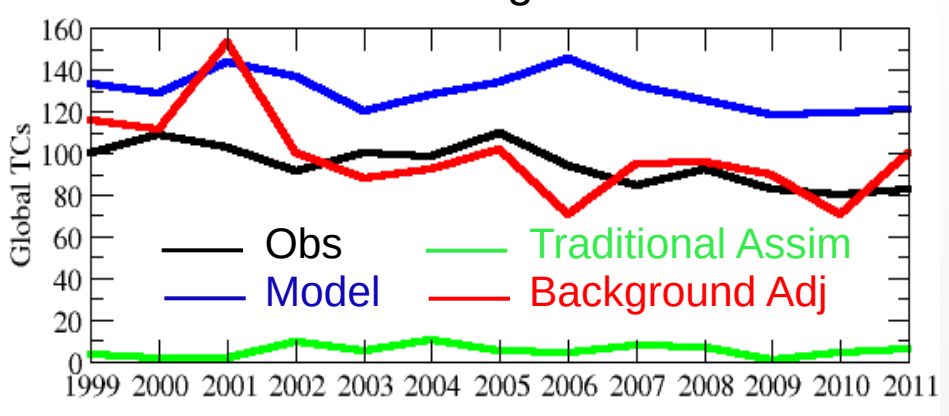
Free model

Traditional scheme

New scheme



Time Series of global TCs



- ✓ Low-resolution observations can wipe out tropical storms
- ✓ Background adjustment can reconstruct TC statistics by correcting large-scale background & retaining small-scale perturbations
- ✓ Minimize model forecast errors allowing interactions of TCs & large-scale background

(Thanks to MZhao & S-J Lin)

Future directions

1. Complete coupled model data assimilation system by including assimilations of sea ice and land obs, extending to estimation of ecosystem fluxes.

2. Implement coupled model parameter estimation into the climate prediction system, continuously improving the forecast skills in SI-decadal scales.

3. Refine the idea that separately processes the large-scale background and small-scale perturbations to advance high-resolution coupled model initialization, pursuing seamless numerical weather-climate studies.